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DRAWING, FORMING AND BENDING DIES

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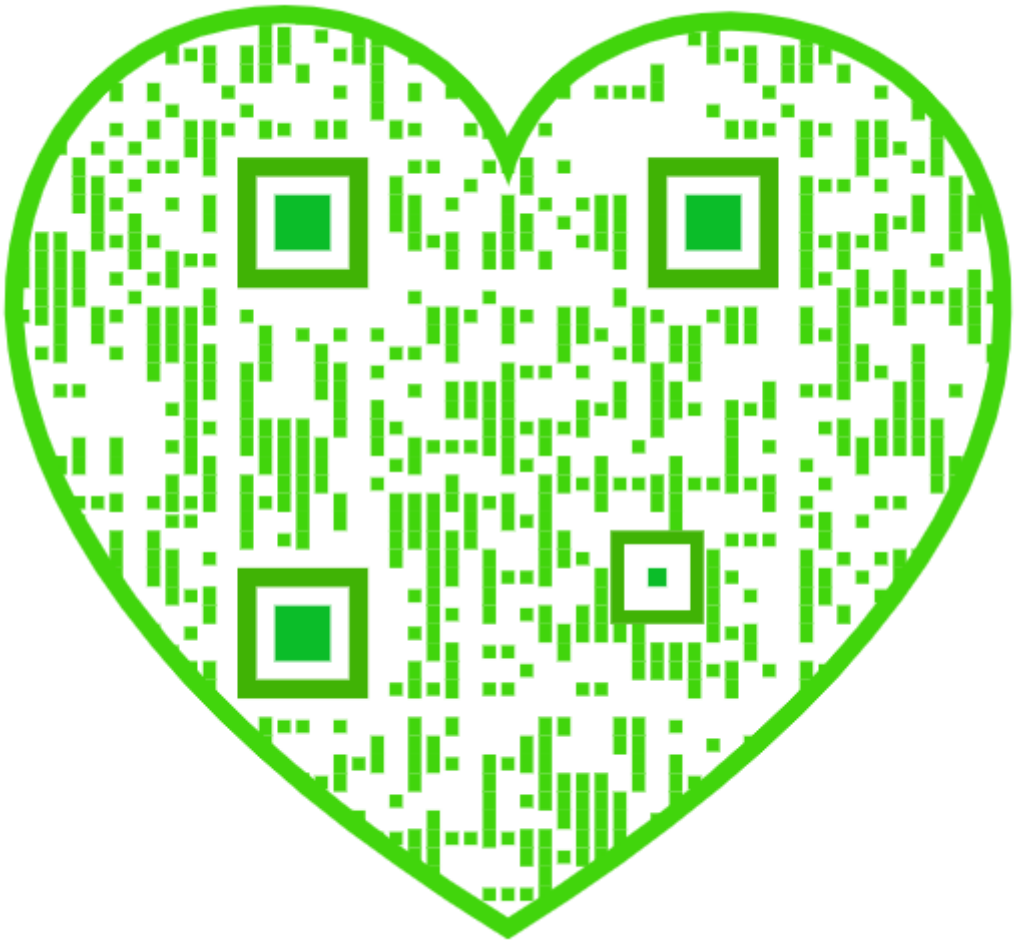

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DRAWING, FORMING AND BENDING DIES

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CHAPTER I

DRAWING AND FORMING DIES

Comparatively little information has been published in book form relating to the subject of drawing dies. This depends partly upon the fact that this line of work in some respects is still in its infancy. While an enormous amount of this kind of work is done daily in hundreds of shops in the country, yet there is a scarcity of definite information as to the fundamental rules that govern this class of work. Some day some one will take up this subject in a manner similar to that in which Mr. F. W. Taylor investigated the art of cutting metals, and then we may be able to lay down exact rules and formulas governing the drawing of metal sheets into shells. At present we must content ourselves with studying a few general principles based upon experience. By giving a great number of examples of work that has been accomplished in practice, the possibilities in this class of work may, however, be indicated.

A large majority of work which, in the past, has been made from castings is now made from sheet steel by drawing up bosses and reinforcing ribs to strengthen the work. The development in the art has been rapid, but has proceeded almost entirely along cut-and-try methods. The definite information that is available, however, relating to the diameters of shell blanks, the depth and diameter reductions of drawn shells, the lubrication of dies, etc., will be given in the following. In addition, a number of practical hints for die-makers in the making of forming dies will be presented, and numerous examples of successful designs of drawing, forming and bending dies. This will give the reader a comprehensive view of the present state of the art.

Diameters of Shell Blanks*

The diameters of blanks for drawing plain cylindrical shells can be obtained from the accompanying table, which gives a very close approximation for thin stock. The blank diameters given in this table are for sharp cornered shells and are found by the following formula:

$$D = \sqrt{d^2 + 4\,dh}, \qquad (1)$$

in which D = diameter of flat blank; d = diameter of finished shell; h = height of finished shell.

Example.—If the diameter of the finished shell is to be 1.5 inch, and the height, 2 inches, the trial diameter of the blank would be found as follows:

$$D = \sqrt{1.5^2 + 4 \times 1.5 \times 2} = \sqrt{14.25} = 3.78 \text{ inches.}$$

For a round-cornered cup, the following formula, in which r equals the radius of the corner, will give fairly accurate diameters, provided

*From MACHINERY'S HANDBOOK, page 979.

the radius does not exceed, say, ¼ the height of the shell:

$$D = \sqrt{d^2 + 4\,dh} - r. \qquad (2)$$

These formulas are based on the assumption that the thickness of the drawn shell is the same as the original thickness of the stock, and that the blank is so proportioned that its area will equal the area of the drawn shell. This method of calculating the blank diameter is quite accurate for thin material, when there is only a slight reduction in the thickness of the metal incident to drawing; but when heavy stock is drawn and the thickness of the finished shell is much less than the original thickness of the stock, the blank diameter obtained from Formulas (1) or (2) will be too large, because when the stock is drawn thinner, there is an increase in area. When an appreciable reduction in thickness is to be made, the blank diameter can be obtained by first determining the "mean height" of the drawn shell by the following formula. This formula is only approximately correct, but will give results sufficiently accurate for most work:

$$M = \frac{ht}{T} \qquad (3)$$

in which M = approximate mean height of drawn shell; h = height of drawn shell; t = thickness of shell; T = thickness of metal before drawing.

After determining the mean height, the blank diameter for the required shell diameter is obtained from the table previously referred to, the mean height being used instead of the actual height.

Example.—Suppose a shell 2 inches in diameter and 3¾ inches high is to be drawn, and that the original thickness of the stock is 0.050 inch, and thickness of drawn shell, 0.040 inch. To what diameter should the blank be cut? Using Formula (3) to obtain the mean height:

$$M = \frac{ht}{T} = \frac{3.75 \times 0.040}{0.050} = 3 \text{ inches.}$$

According to the table, the blank diameter for a shell 2 inches in diameter and 3 inches high is 5.29 inches. This formula is accurate enough for all practical purposes, unless the reduction in the thickness of the metal is greater than about one-fifth the original thickness. When there is considerable reduction, a blank calculated by this formula produces a shell that is too long. This, however, is an error in the right direction, as the edges of drawn shells are ordinarily trimmed. If the shell has a rounded corner, the radius of the corner should be deducted from the figures given in the table. For example, if the shell referred to in the foregoing example had a corner of ¼-inch radius, the blank diameter would equal 5.29 — 0.25 = 5.04 inches.

Another formula which is sometimes used for obtaining blank diameters for shells, when there is a reduction in the thickness of the stock, is as follows:

DIAMETERS OF BLANKS FOR DRAWN SHELLS

Diameter	Height of Shells																							
	¼	½	¾	1	1¼	1½	1¾	2	2¼	2½	2¾	3	3¼	3½	3¾	4	4¼	4½	4¾	5	5¼	5½	5¾	6
¼	.56	.75	.90	1.03	1.14	1.25	1.35	1.44	1.52	1.60	1.68	1.75	1.82	1.89	1.95	2.01	2.08	2.14	2.19	2.25	2.30	2.36	2.41	2.46
½	.87	1.12	1.32	1.50	1.66	1.80	1.94	2.06	2.18	2.29	2.40	2.50	2.60	2.69	2.78	2.87	2.96	3.04	3.12	3.21	3.29	3.36	3.44	3.50
¾	1.14	1.44	1.68	1.89	2.08	2.25	2.41	2.56	2.70	2.84	2.97	3.09	3.21	3.33	3.44	3.54	3.65	3.75	3.85	3.95	4.04	4.13	4.22	4.31
1	1.41	1.73	2.00	2.24	2.45	2.65	2.83	3.00	3.16	3.32	3.46	3.61	3.74	3.87	4.00	4.12	4.24	4.36	4.47	4.58	4.69	4.80	4.90	5.00
1¼	1.68	2.01	2.30	2.56	2.79	3.01	3.21	3.40	3.58	3.75	3.91	4.07	4.22	4.37	4.51	4.64	4.77	4.91	5.03	5.15	5.27	5.39	5.50	5.62
1½	1.94	2.29	2.60	2.87	3.12	3.36	3.57	3.78	3.97	4.15	4.33	4.50	4.66	4.82	4.98	5.12	5.27	5.41	5.55	5.68	5.81	5.94	6.06	6.18
1¾	2.19	2.56	2.88	3.17	3.44	3.68	3.91	4.13	4.34	4.53	4.72	4.91	5.08	5.26	5.41	5.58	5.73	5.88	6.03	6.17	6.31	6.45	6.58	6.71
2	2.45	2.83	3.16	3.46	3.74	4.00	4.24	4.47	4.69	4.90	5.10	5.29	5.48	5.66	5.83	6.00	6.16	6.32	6.48	6.63	6.78	6.93	7.07	7.21
2¼	2.70	3.09	3.44	3.75	4.04	4.31	4.56	4.80	5.03	5.25	5.46	5.66	5.86	6.05	6.23	6.41	6.58	6.75	6.91	7.07	7.23	7.39	7.54	7.69
2½	2.96	3.36	3.71	4.03	4.33	4.61	4.87	5.12	5.36	5.59	5.81	6.02	6.22	6.42	6.61	6.80	6.98	7.16	7.33	7.50	7.66	7.82	7.98	8.14
2¾	3.21	3.61	3.98	4.31	4.62	4.91	5.18	5.44	5.68	5.92	6.15	6.37	6.58	6.79	6.99	7.18	7.37	7.55	7.73	7.91	8.08	8.25	8.41	8.58
3	3.46	3.87	4.24	4.58	4.90	5.20	5.48	5.74	6.00	6.25	6.48	6.71	6.93	7.14	7.35	7.55	7.75	7.94	8.12	8.31	8.49	8.66	8.83	9.00
3¼	3.71	4.13	1.51	4.85	5.18	5.48	5.77	6.04	6.31	6.56	6.80	7.04	7.27	7.49	7.70	7.91	8.11	8.31	8.50	8.69	8.88	9.06	9.24	9.41
3½	3.97	4.39	4.77	5.12	5.45	5.77	6.06	6.34	6.61	6.87	7.12	7.36	7.60	7.83	8.05	8.26	8.47	8.67	8.87	9.07	9.26	9.45	9.63	9.81
3¾	4.22	4.64	5.03	5.39	5.73	6.05	6.35	6.64	6.91	7.18	7.44	7.69	7.92	8.16	8.38	8.61	8.82	9.03	9.24	9.44	9.63	9.83	10.02	10.20
4	4.47	4.90	5.29	5.66	6.00	6.32	6.63	6.93	7.21	7.48	7.75	8.00	8.25	8.49	8.72	8.94	9.17	9.38	9.59	9.80	10.00	10.20	10.39	10.58
4¼	4.72	5.15	5.55	5.92	6.27	6.60	6.91	7.22	7.50	7.78	8.05	8.31	8.56	8.81	9.04	9.28	9.50	9.72	9.94	10.15	10.36	10.56	10.76	10.96
4½	4.98	5.41	5.81	6.19	6.54	6.87	7.19	7.50	7.79	8.08	8.35	8.62	8.87	9.12	9.37	9.60	9.84	10.06	10.28	10.50	10.71	10.92	11.12	11.32
4¾	5.22	5.66	6.07	6.45	6.80	7.15	7.47	7.78	8.08	8.37	8.65	8.92	9.18	9.44	9.69	9.93	10.16	10.40	10.62	10.84	11.06	11.27	11.48	11.69
5	5.48	5.92	6.32	6.71	7.07	7.42	7.75	8.06	8.37	8.66	8.94	9.22	9.49	9.75	10.00	10.25	10.49	10.72	10.95	11.18	11.40	11.62	11.83	12.04
5¼	5.73	6.17	6.58	6.97	7.33	7.68	8.02	8.34	8.65	8.95	9.24	9.52	9.79	10.05	10.31	10.56	10.81	11.05	11.28	11.51	11.74	11.96	12.18	12.39
5½	5.98	6.42	6.84	7.23	7.60	7.95	8.29	8.62	8.93	9.23	9.53	9.81	10.08	10.36	10.62	10.87	11.12	11.37	11.61	11.84	12.07	12.30	12.52	12.74
5¾	6.23	6.68	7.09	7.49	7.86	8.22	8.56	8.89	9.21	9.52	9.81	10.10	10.38	10.66	10.92	11.18	11.44	11.69	11.93	12.17	12.40	12.63	12.85	13.08
6	6.48	6.98	7.35	7.75	8.12	8.49	8.83	9.17	9.49	9.80	10.10	10.39	10.68	10.95	11.23	11.49	11.75	12.00	12.25	12.49	12.73	12.96	13.19	13.42

$$D = \sqrt{a^2 + \left(a^2 - b^2\right)\frac{h}{t}} \qquad (4)$$

In this formula D = blank diameter; a = outside diameter; b = inside diameter; t = thickness of shell at bottom; h = depth of shell. This formula is based on the cubic contents of the drawn shell. It is assumed that the shells are cylindrical, and no allowance is made for a rounded corner at the bottom, or for trimming the shell after drawing. To allow for trimming, add the required amount to depth h. When a shell is of irregular cross-section, if its weight is known, the blank diameter can be determined by the following formula:

$$D = 1.1284\sqrt{\frac{W}{wt}} \qquad (5)$$

in which D = blank diameter in inches; W = weight of shell; w = weight of metal per cubic inch; t = thickness of the shell.

In the construction of dies for producing shells, especially of irregular form, a common method of procedure is to make the drawing parts first. The actual blank diameter can then be determined by trial. One method is to cut a trial blank as near to size as can be estimated. The outline of this blank is then scribed on a flat sheet, after which the blank is drawn. If the finished shell shows that the blank is not of the right diameter, a new trial blank is cut either larger or smaller than the size indicated by the line previously scribed, this line acting as a guide. If a model shell is available, the blank diameter can also be determined as follows: First cut a blank somewhat large, and from the same material used for making the model; then reduce the size of the blank until its weight equals the weight of the model.

Depth and Diameter Reductions of Drawn Shells

The depth to which metal can be drawn in one operation depends upon the quality and kind of material, its thickness, the slant or angle of the dies, and the amount that the stock is thinned or "ironed" in drawing. A general rule for determining the depth to which cylindrical shells can be drawn in one operation is as follows: The depth or length of the first draw should never be greater than the diameter of the shell. If the shell is to have a flange at the top, it may not be practicable to draw as deeply as is indicated by this rule, unless the metal is extra good, because the stock is subjected to a higher tensile stress, owing to the larger blank which is necessary for forming the flange. According to another rule, the depth given the shell on the first draw should equal one-third the diameter of the blank. Ordinarily, it is possible to draw sheet steel of any thickness up to ¼ inch, so that the diameter of the first shell equals about six-tenths of the blank diameter. When drawing plain shells, the amount that the diameter is reduced for each draw must be governed by the quality of the metal and its susceptibility to drawing. The reduction for various

thicknesses of metal is about as follows:

Approximate thickness of sheet steel....	1/16	1/8	3/16	1/4	5/16
Possible reduction in diameter for each succeeding step, per cent.....	20	15	12	10	8

For example, if a shell made of 1/16-inch stock is 3 inches in diameter after the first draw, it can be reduced 20 per cent on the next draw, and so on until the required diameter is obtained. These figures are based upon the assumption that the shell is annealed after the first drawing operation, and at least between every two of the following operations. Necking operations—that is, the drawing out of a short portion of the lower part of the cup into a long neck—may be done without such frequent annealings. In double-action presses, where the inside of the cup is supported by a bushing during drawing, the reductions possible may be increased to 30, 24, 18, 15 and 12 per cent, respectively. (The latter figures may also be used for brass in single-action presses.)

When a hole is to be pierced at the bottom of a cup and the remaining metal is to be drawn after the hole has been pierced or punched, always pierce from the opposite direction to that in which the stock is to be drawn after piercing. In extreme cases, it is necessary to machine the metal around the pierced hole in order to prevent the starting of cracks or flaws in the subsequent drawing operations.

The foregoing figures represent conservative practice and it is often possible to make greater reductions than are indicated by these figures, especially when using a good drawing metal. Taper shells require smaller reductions than cylindrical shells, because the metal tends to wrinkle if the shell to be drawn is much larger than the punch. The amount that the stock is "ironed" or thinned out while being drawn must also be considered, because a reduction in gage or thickness means greater pressure of the punch against the bottom of the shell; hence the amount that the shell diameter is reducd for each drawing operation must be lessened when much ironing is necessary. The extent to which a shell can be ironed in one drawing operation ranges between 0.002 and 0.004 inch per side, and should not exceed 0.001 inch on the final draw, if a good finish is required.

Prevention of Wrinkles in Drawn Work

The formation of wrinkles in drawing operations is a source of great trouble, and there are many pieces of drawn work which could be performed in a single operation were it not for the wrinkles that would inevitably appear. In drawing operations, the tendency to wrinkle starts with the first contact of the punch upon the metal.

The usual method of preventing wrinkles is to provide the punch with a blank-holder which is operated by springs of sufficient tension to allow the metal to be pulled from beneath it for drawing, but maintaining pressure enough to keep the metal free from wrinkles. At *A*, in Fig. 1, is shown a section of a simple drawing die in which it will be noticed that the die is provided with a raised ridge around its

opening, the blank-holder having a corresponding depression. Consequently, the sheet metal being drawn is pulled over this ridge, and as the space between the blank-holder and the top of the ridge is purposely made slightly less than the thickness of the metal, it will be seen that as the stock passes through this opening any wrinkles are "ironed out." At *B*, the shell from the dies at *A* is shown undergoing a second operation.

For strength and protection in hardening, as well as to facilitate the drawing operation, the ridge is provided with a fillet where it joins the flat surface of the die. It is obvious that the addition of this ridge to the drawing die occasions a little extra work in the die-making, but this work is offset by the fact that the blank-holder and upper surface of the drawing die do not have to be ground perfectly smooth and parallel, as is ordinarily required. The size of the ridge around the die should be in proportion to the diameter of the shell. A shell 4 inches in diameter is most easily drawn with a die having a ridge of

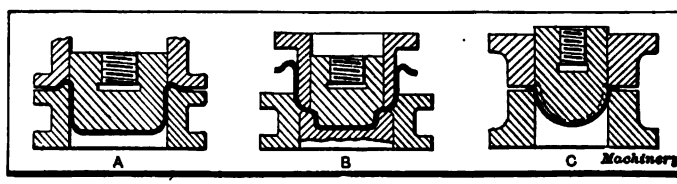


Fig. 1. A Method of Drawing Sheet Metal by Means of which Wrinkling of the Stock is avoided

7/16 inch radius. For a shell of 8 inches diameter the radius of the ridge should be ½ inch. For a shell 12 inches in diameter the radius of the ridge should be ⅝ inch. For a shell 16 inches in diameter the radius of the ridge should be ¾ inch, and a shell 20 inches in diameter would require a ridge having a radius of 1 inch.

It is obvious that the completed shell will have a ridge left at the edge. On work which is to be wired or for work on which the edge is to be turned over, this additional ridge is no detriment as it can be made use of directly. Moreover, if a succeeding operation is to follow, deepening the shell slightly, this ridge will provide the surplus metal required. This point is illustrated at *C*. In other cases, the extra metal left at the edge may be removed when the shell is trimmed. It is claimed that this improvement in drawing dies is being employed with success. By its use, wrinkles are absolutely prevented, and, moreover, the drawing operation puts less stress upon the metal.

Practical Hints for Diemakers in making Drawing and Forming Dies

In making templets and blanks, always file them straight and square across the edge. In developing the blank always keep a templet or reference blank, so that it will be at hand if alterations are found necessary. Each time a change is made the previous blank which was kept for reference is marked to designate it from others. The marks may be "M" for model or "S" for sample. It should be remem-

bered that metal will not draw around sharp corners, and that corners over which the metal is to be drawn should be rounded to a true radius. In all cases when making blanks for forming punches and dies consider the thickness of the metal.

In forming blanks they should always be bent with the grain of the metal and not across it, particularly on sharp bends. By the "grain" is meant the way in which the metal is drawn when passing through the rolls. If it is required to make bends at right angles to each other or approximately so, the blanks should be punched out diagonally across the grain. It is sometimes found necessary to form blanks from unannealed stock, that is stock which has been rolled to a certain degree of hardness. In bending this metal it springs back more or less after being struck in the die. This makes it necessary to make a more acute angle or a smaller radius on the punch and die, than is required on the finished product. This difference can be ascertained only by the cut-and-try method. When producing a short bend in blanks in such a position and of such a nature that the blank slips away from under the punch when it is descending into the die, a spring pad is fitted into the die with the lower part of the bend shaped into it, and flush with the top surface of the die. This holds the metal securely against the punch in its descent into the die and insures perfect duplicates of the product. Where holes in a blank come near a bend, a strain in the metal is set up during the bending operation which elongates the holes. This makes it necessary sometimes to pierce the holes slightly oval in the opposite direction before forming. In testing the shape of a forming die before it is hardened, always apply a small amount of oil to the surface so that the blank will not bruise or scratch the die, which would be the case if the die were left dry.

Never leave the inside corners of a die sharp when they can just as easily conform to the radius formed by bending the stock around the punch. This will strengthen the die and lessen the possibility of its cracking when hardened. When necessary, one forming die can be made to form bends in several pieces which have the same form but are of different lengths. This is accomplished by equipping the die with interchangeable gages or guide strips. Never leave any file marks on the working portions of the punch or die, as these will be reproduced on the blank. A screw hole in a die should be tapped a little larger than the screw, as the die shrinks somewhat in hardening.

When a punch or die is heated in a charcoal or a soft coal fire, the dust and ashes should be thoroughly scraped off the working portion before dipping, so that the water will have a free action upon the steel. Bending and forming dies, unless there is danger of cracking or breaking of weak parts, should be as hard as fire and water will make them. After hardening they may be warmed over a slow fire until water "sizzles" on them. Some toolmakers, when hardening a punch or die, apply cyanide of potassium to the working portions of the steel before dipping. They claim for this that the outer surface of the steel

is rendered harder by the application of this casehardening substance and thus will be better fitted to withstand the wear to which it is subjected. This practice is strongly condemned for this reason: If, as is often the case, the tool should fail to harden, this fact will be concealed by the casehardened outer coating, and the tool will respond to the file test as being hard whether it is or not.

Gage plates should never be secured with two screws and one dowel pin. It is far more practical to use one screw and two dowel pins in most cases. A good method of holding gage plates before their exact position is determined is to clamp them to the die with fillister screws having washers under their heads, and to drill the holes in the gage plate about 1/16 inch larger than the diameter of the screws, so that the gage plate may be shifted around. Always drill the screw holes for the gage plates through the die so that in case a new gage plate is required the holes will be spotted from the die. Whenever the gage plate comes close to the working portion of the die, cut the punch back far enough so that the body of the punch will come within ⅛ or ¼ inch of the gage plate. In making gage plates for locating large blanks of irregular shape, they should be made to fit the blank only at the point where accuracy is essential, and not to conform exactly to the irregular shape of the blank.

Wood fiber may be formed in the press into almost any shape, but before shaping, it should be immersed in a solution of hot water and soda for a few minutes and then subjected to heavy pressure in the press.

When setting up a press for forming operations the blank as formed by the tools is used to locate the punch in the die before securing the die to the press. If the tools are being tried out for the first time and no sample has been made, they may be set with strips of metal cut from the stock to be formed. When setting the die for a piece in which the bends are not parallel but off at an angle, it is usually impracticable to set them with a previous blank, because when the punch is brought down, the tendency is to push both die and blank away. The more practical method is to locate it approximately with the blank and slightly tighten the screws in the press bed; then with two strips of metal the same size as the blank, gage the exact distance, after which the die can be secured to the press.

Do not assume that a die is certain to be satisfactory when the samples have been produced by bringing down the press slowly by hand, as there is sometimes more or less variation in what the tools will do when operated by hand and when operated by power.

Lubricants for Drawing and Forming

For drawing steel, the following mixture is recommended as a lubricant: 25 per cent flaked graphite; 25 per cent beef tallow; and 50 per cent lard oil. This mixture should be heated and the work dipped into it. Oildag mixed with heavy grease is also used for steel, and a thin mixture of grease (preferably tallow) and white lead has

proved satisfactory. The following compound is also used for drawing sheet steel of a mild grade: Mix one pound of white lead, one quart of fish oil, three ounces of black lead, and one pint of water. These ingredients should be boiled until thoroughly mixed. For working brass or copper, a solution composed of 15 pounds of Fuller's soap to a barrel of hot water (used hot), or any soap strong in rosin or potash, is cheaper and cleaner than oil. The stock should pass through a tank filled with this solution before entering the dies. For cutting aluminum, use kerosene, and for drawing aluminum, use vaseline of a cheap grade. Lard oil is also applied to aluminum when drawing deep shells. Aluminum should never be worked without a lubricant. For many classes of die work, no lubricant is required, especially when the metal is of a "greasy" nature, like tin plate, for instance.

Annealing Drawn Shells

When drawing steel, iron, brass or copper, annealing is necessary after two or three draws have been made, as the metal is hardened by the drawing process. For steel and brass, anneal between every other reduction, at least. Tin plate or stock that cannot be annealed without spoiling the finish must ordinarily be drawn to size in one or two operations. Aluminum can be drawn deeper and with less annealing than the other commercial metals, provided the proper grade is used. In case it is necessary to anneal aluminum, this can be done by heating it in a muffle furnace, care being taken to see that the temperature does not exceed 700 degrees F.

Drawing Brass

When drawing brass shells or cup-shaped articles, it is usually possible to make the depth of the first draw equal to the diameter of the shell. By heating brass to a temperature just below what would show a dull red in a dark room, it is possible to draw difficult shapes, otherwise almost impossible, and to get shapes with square corners.

Drawing Rectangular Shapes

When square or rectangular shapes are to be drawn, the radius of the corners should be as large as possible, because it is in the corners that defects occur when drawing. Moreover, the smaller the radius, the less the depth which can be obtained in the first draw. The maximum depths which can be drawn with corners of a given radii are approximately as follows: With a radius of 3/32 to 3/16 inch, depth of draw, 1 inch; radius 3/16 to 3/8 inch, depth, 1½ inch; radius ⅜ to ½ inch, depth, 2 inch; radius ½ to ¾ inch, depth, 3 inches. These figures are taken from actual practice and can doubtless be exceeded slightly when using extra good metal. If the box needs to be quite deep and the radius is quite small, two or more drawing operations will be necessary.

Drawing a Flanged and Tapered Cylindrical Shell

In the production of cylindrical shells from flat stock, the construction of the tools and the number of operations or steps in their development depend entirely upon what the ultimate shape is to be. Thus, when it is desired to produce a straight cylindrical shell of a depth not exceeding, say, twice the diameter, the first operation may be accomplished in a combination blanking and drawing die, which will cut the blank and draw it to a height almost equal to the diameter. If a flange is left around the shell, the die can be used in a single-action press, a rubber spring barrel being used to create pressure on the blank. If no flange is left on the shell, a double-action press is used and all of the blank area worked into the shell, the metal being drawn through the die, and the shell stripped on the under edge of the drawing die at the commencement of the return stroke. After this first operation, two, or at the most, three redrawing operations, each accomplishing an approximately equal reduction in diameter and increase in depth, will attain the desired result. In such work, the evolution of the shape and the dimensions can usually be planned accurately without trouble before starting the construction of the tools, and the blanking die can be made to size with the certainty that just the right amount of stock will be contained in the blank to produce a shell of the required form, diameter and depth.

When the shell height does not exceed the shell diameter, only a slight variation will take place in the thickness of the wall, and the final thickness will not differ materially from the original blank thickness, that is, if the metal drawn is perfectly soft to commence with and the product of each drawing operation is annealed before reducing. If the holes in the drawing dies are lapped, the punches fitted properly and given just sufficient taper to allow the shell to be stripped without collapsing the rim, an elegant surface will be attained and the shell diameter will be true.

In drawing tapered cylindrical shells with flanges, the requirements for the construction of the dies and the evolution of the shell shapes are different. When the taper in the finished shell is considerably acute in comparison with the height and diameter, the desired result can only be accomplished as shown in Figs. 2 to 6 inclusive. To attain these results, it is first necessary to bring the blank into a cylindrical shape, the area of which will just equal that of the metal required in the finished shell. When trouble is experienced in drawing tapered shells, it is almost invariably caused through the die-maker endeavoring to generate the acute taper in the first operation, or to draw it directly from the flat blank. When this practice is followed the shell is either split at the bottom, or waves and wrinkles are formed in the wall of the shell which cannot be removed. Another frequent cause of trouble lies in having a surplus of metal in the shell, and the consequent inability to distribute it in the finishing operation or to return it to the flange from which it was drawn.

When the proper amount of metal is contained in the shell form

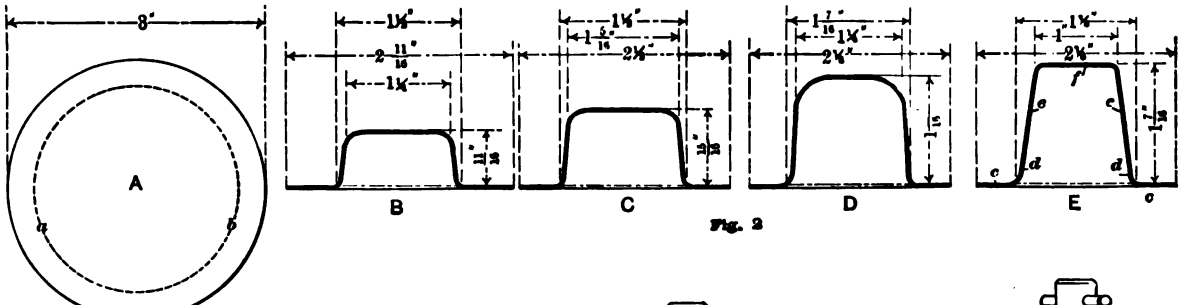


Fig. 2

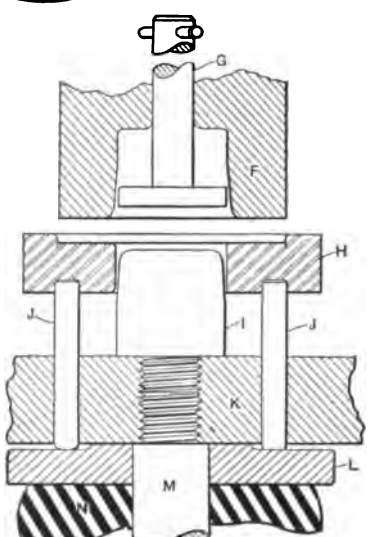
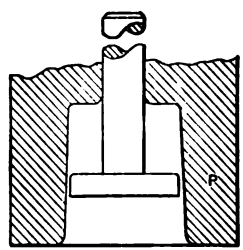


Fig. 3



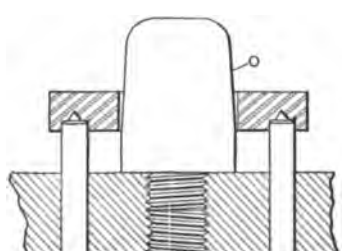
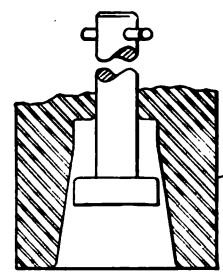


Fig. 4



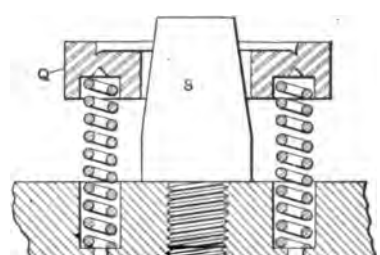


Fig. 5

Machinery

Fig. 2. Development, Evolution and Dimensions of a Flanged and Tapered Cylindrical Shell. Fig. 3. The Drawing Punch and Die for the Cups shown at B and C, Fig. 2. Fig. 4. Redrawing Punch and Die for Operation shown at D. Fig. 5. The Finishing Punch and Die for Operation shown at E

as shown at *D*, Fig. 2, with slightly tapering walls, a succeeding operation of reforming—not drawing or reducing through friction—will shape the cylindrical shell to the desired taper. The reason for this practice is that in drawing a straight cylindrical shell or even one slightly tapering, the metal is confined at all times during the process of drawing between the die and punch surfaces, making the inception of wrinkles impossible and the flow of metal equal and constant during the entire operation. When the depth to be drawn is quite shallow as compared with the shell diameter, even acute tapers can sometimes be accomplished in one operation.

Fig. 6 shows clearly the result of each operation, while Fig. 2 illustrates the various steps necessary to develop the final form completely. In Fig. 2, *A* is the blank, 3 inches in diameter by 0.032 inch thick—No. 20 Brown & Sharpe gage. The blank was cut in a plain blanking die in an automatic press. *B* is the result of the second operation, and is accomplished in the die shown in Fig. 3, as is also the redrawing operation *C*, the die remaining unchanged, except that a thinner locating pad and blank-holder was substituted for the one shown at *H*. In Fig. 3, *F* is the drawing die, *G* the shell ejector, *H* the blank-holder and locater, *I* the drawing punch, *J* two of five spring barrel pins, *K* the die-bolster, *L* one of the two spring barrel-washers, *M* the barrel stud, and *N* the rubber spring barrel, only a section of which is shown, it being circular, 4 inches in diameter by 6 inches high with a 1-inch hole through it.

At *C* in Fig. 2, it will be noticed that an increase of ¼ inch in height and 1/16 inch in top diameter is attained. At *D* the height is increased to 1 5/16 inch—a gain of 3/8 inch—and at *E* the shell is completed to a height of 1 7/16 inch, the smallest diameter being 1 inch and the largest 1⅜ inch with a flange diameter of 2⅜ inches. The dotted line *a b* at *A* in Fig. 2 shows the amount of metal drawn from the blank to form the entire cone of the shell at *E*.

Fig. 4 shows the tools used for accomplishing the operation shown at *D* in Fig. 2. A spring buffer, not shown, is used as in Fig. 3, and the cup *C*, Fig. 2, is located on the punch *O*, the die *P* descending and drawing the cup to the shape shown at *D*.

In the finishing punch and die shown in Fig. 5, no drawing of the metal takes place, the displacement of the wall of the shell and reshaping alone being accomplished. Only a slight description is necessary to understand the operation of the die shown in Fig. 5. The shell *D* is located in a seat in the holder *Q*, and the die *R* descends, holding the flange of the shell tightly between the faces of *Q* and *R*, while the punch *S* forms the shell into the tapered shape shown at *E*. At the bottom of the stroke, pressure occurs on all surfaces of the shell, shaping it to a tapered and cylindrical form.

In the evolution of the finished shell the following changes take place in the wall and flange thickness: At *c* (see *E* Fig. 2) the metal is reduced to 0.030 inch, at *d* to 0.022 inch, at *e* to 0.018 inch, and at *f* to 0.021 inch. It was necessary to anneal the shell twice, after

Fig. 6. The Successive Operations in the Production of a Flanged and Tapered Cylindrical Shell

the first draw and after the third or redrawing operation. To secure satisfactory results the annealing has to be accomplished without producing a surface scale, as the scale would prevent the attainment of smoothness and accuracy in the finished product.

Thin lard oil was used as a lubricant during the first two drawing operations, and then the shells were run dry and clean through the last two operations. No fractured shells came through, and the tools produced a large quantity of the shells which were used in molding fixtures for brass articles reinforced with cement. The drawing pads, punches and spring buffer pins used in the dies shown in Figs. 3 and 4, were made of steel, the other parts being made of cast iron. For the finishing die, Fig. 5, steel was used throughout for all the working parts, and the pad and die surfaces were hardened and lapped to a finish.

In drawing tapered shells of the type shown in Figs. 2 and 6, in which a uniform thickness of wall throughout is not demanded, a slight insufficiency of metal in the product of the next to the last operation is best, as the finishing tool can then stretch the metal so as to bring the surface and diameter perfectly smooth and true.

Dies for Drawing a Deep Steel Shell

Figs. 8 to 11 show a set of drawing dies made for producing a steel can 4 inches in diameter and 8⅝ inches long, with a 3/32-inch shoulder formed at an angle of 15 degrees with the sides. Fig. 7 shows the blank *A* and the successive drawing operations. The blank is made from sheet steel, 1/16 inch thick, and is 12¾ inches in diameter.

The first drawing or cupping die is shown in Fig. 8, and the cup produced in this die is shown at *B* in Fig. 7. The die bed *A*, Fig. 8, is made from cast iron, while the drawing die *B* is made from machine steel, pack-hardened. The punch *C* is also made from machine steel, and pack-hardened, and the blank-holder *D* is made from cast iron,

faced with a hardened machine-steel ring *E*. The cup is stripped from the punch by means of the finger *F*, acted upon by the spiral spring shown.

The construction of the second drawing die, shown in Fig. 9, is substantially the same as that shown in Fig. 8, except that it is provided with a gage-plate *G* for holding the cup. The length of the shell produced by the die shown in Fig. 9 is indicated at *C* in Fig. 7. After these two drawing operations the shell is annealed, and then put through the die shown in Fig. 10. The construction of this die is similar to that shown in Fig. 9.

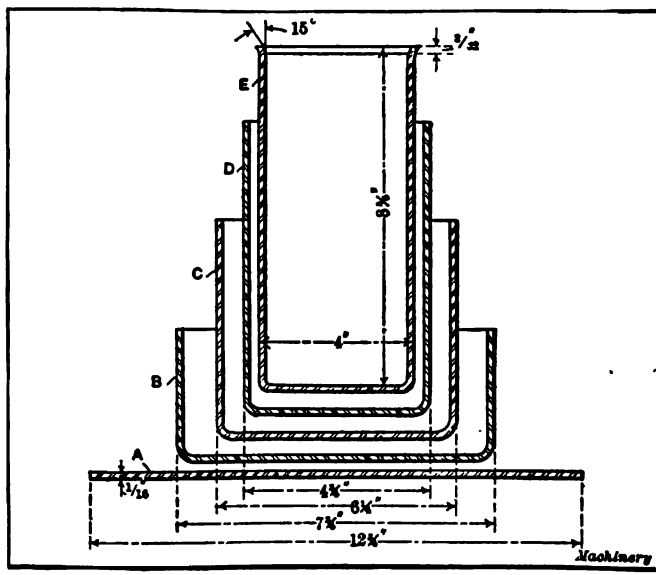


Fig. 7. The Blank and the Successive Drawing Operations

The cup *D*, after the third drawing operation, was too long to be inserted in the press available for the fourth drawing operation, and had to be trimmed down to 7½ inches. The shell is kept in an upright position in the die, Fig. 11, by a ring gage or guide *A*, which fits in the top of the shell when it is located in the die, and holds it while the punch forces it through. The distance between the bed and the ram of the press was not sufficient to allow the use of this guide without trimming the shell, which operation could have been dispensed with if a suitable press had been available.

The shell was annealed after the third drawing operation, and then put through the finish-drawing die shown in Fig. 11, after which it was trimmed to the required length. The last drawing die, Fig. 11, is provided with a knockout *B*, which was necessary, as it was impossible to force the shell through the die in this operation, on account of the

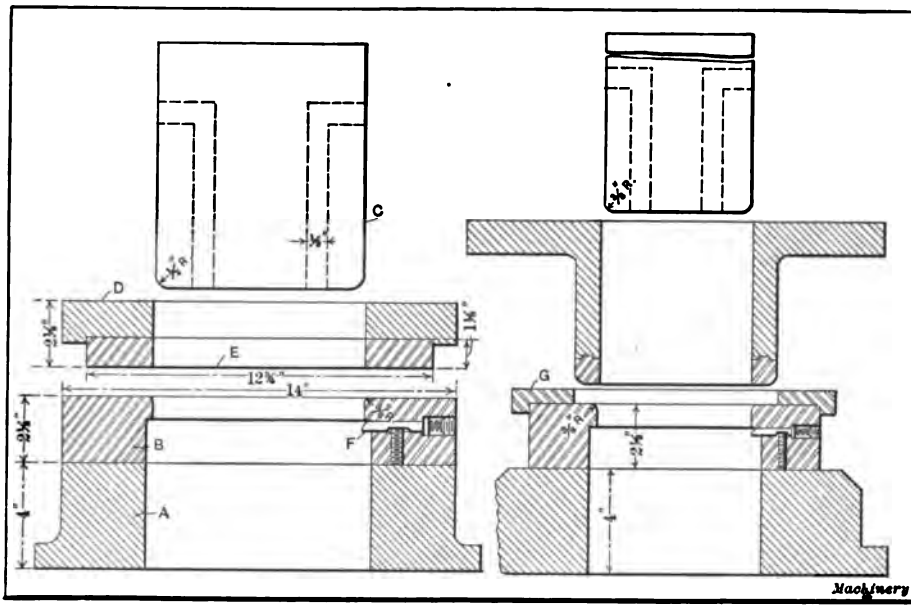
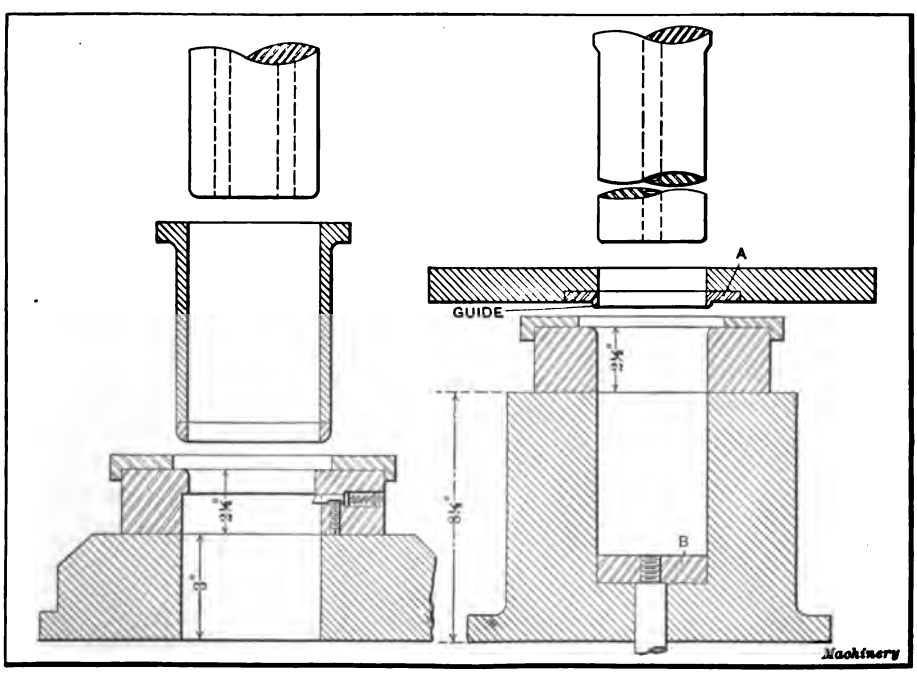


Fig. 8. Punch and Die for Forming the Cup

Fig. 9. Punch and Die for Second Operation



Figs. 10 and 11. Punches and Dies for the Third and Fourth Drawing Operations

punch forming a flange on it, as shown at *E* in Fig. 8. All the drawing punches were provided with air passages, and the drawing faces of the blank-holders were made from tool steel and hardened.

Drawing a Cold-rolled Steel Shell

In Fig. 12 is shown a cold-rolled steel shell to be drawn. The following sizes of dies for the various drawing operations will be found

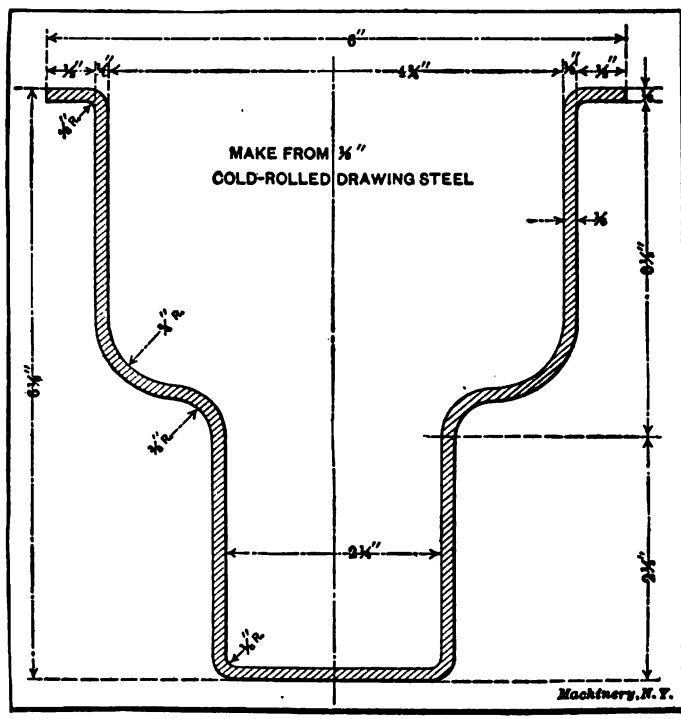


Fig. 12. Steel Shell to be drawn

suitable for making this shell:

Diameter of first drawing die	= 9⅛ inches,
Diameter of second drawing die	= 7½ inches,
Diameter of third drawing die	= 6⅛ inches,
Diameter of fourth drawing die	= 5 inches,
Diameter of fifth drawing die for reducing shoulder	= 4 inches,
Diameter of sixth drawing die for reducing shoulder	= 3¼ inches,
Diameter of seventh drawing die for reducing shoulder	= 2 9/16 inches,
Finished drawing die for shoulder	= 2½ inches.

All these drawing dies are of the same type as those used in a double-action drawing press. The dies are made from cast iron with hardened steel drawing surfaces, and the shell is shoved through and not returned, to avoid scratching, except in the operations for reducing the shoulder or lower part of the shell where it is necessary to remove the shell by the knock-out. In the drawing operations previous to reducing the shoulder, the shell is stripped from the punch by projection *F* on the die (see Fig. 14).

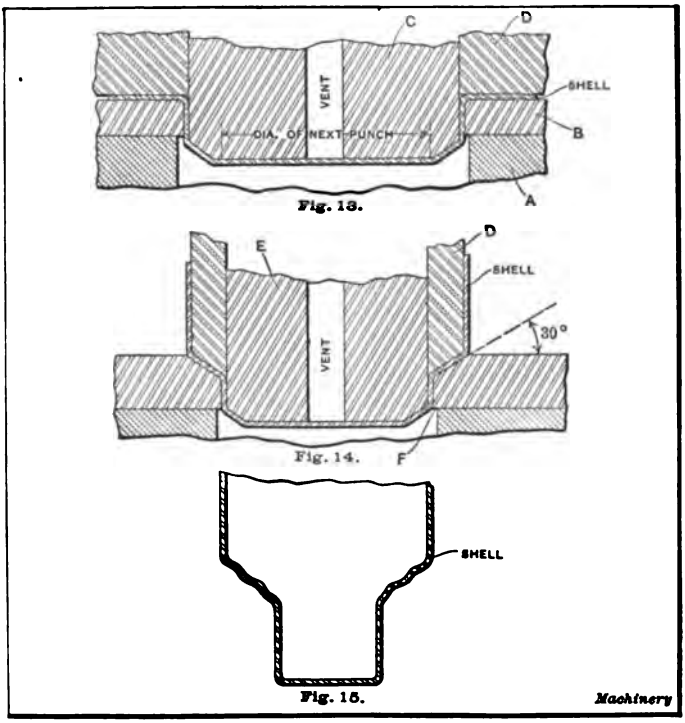


Fig. 13. First Drawing Die. Fig. 14. Redrawing Die. Fig. 15. Shape of the Shell after Reducing the Shoulder

The first drawing die is shown in Fig. 13, where *A* is the cast-iron base, *B* the tool-steel face, *C* the punch, and *D* the double-action blank holder which has a steel face. The punch is provided with a vent hole, as in the case with all the other drawing punches. The correct shape of the punch is shown in the illustration. In Fig. 14 the redrawing die is shown. This die is of the same construction as that shown in Fig. 13, except that it is provided with a drawing angle of 30 degrees, which facilitates the drawing or "flowing" of the metal. The shell, in this case, is held by a blank holder *D*, which is actuated by the double-action of the press, and holds the blank with sufficient pressure to prevent it from buckling when being drawn out by the

punch *E*. The dies for the successive redrawing operations up to the point where the shoulder is reduced, are of similar construction to that shown in Fig. 14. The redrawing dies for the reducing of the shoulder are also somewhat similar in design to that shown in Fig. 14, except that the shell is not forced through the die, but is returned by the knock-out bar of the press.

The punch and die for finish drawing and "ironing" out ridges in the shell is shown in Fig. 16. The die *G* is made of tool steel, as is

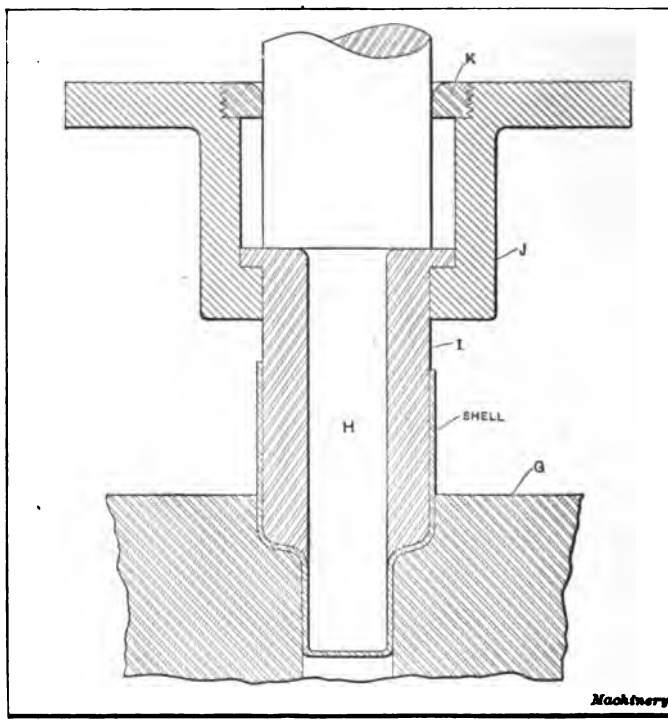


Fig. 16. Punch and Die for Finish Drawing

also the punch *H* and the double-action blank holder *I*. The blank holder *I* is held in a bolster *J*, which, in turn, is fastened to the ram of the press. A collar *K* is screwed into the top of the bolster to stop the upward stroke of the blank holder until the shoulder on the punch comes in contact with it. The idea of using a double-action press and a die along the lines shown in Fig. 16 is to throw the blow on the punch and crankshaft of the press, instead of on the toggles. This also insures the stripping of the shell from the punch, as the small end of the shell, which is brought down to size, is likely to stick in the die in this operation. Having a die of this construction also facilitates the stripping of the shell from the blank holder. The

shape of the shell up to and beyond the shoulder is indicated in Fig. 15 where slight ridges are shown at the shoulder. These ridges are caused by the successive re-drawing operations.

The writer would call the reader's attention to the gradual decrease in the metal after each successive drawing operation. It is evident, of course, that the diameter of the shell must become less as it is reduced, so that the metal will not be subjected to excessive strain. The second drawing operation, that is, the first operation after the cup has been formed, reduces the shell from 9⅛ inches to 7½ inches or

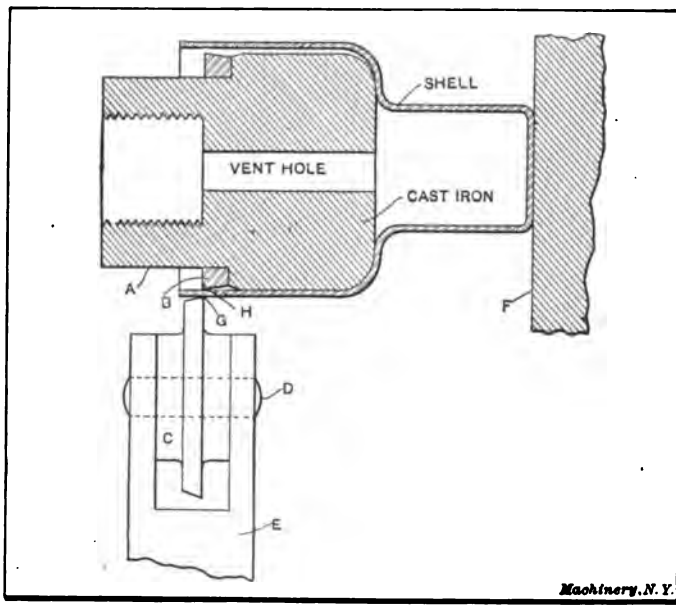


Fig. 17. Trimming the Shell to Length

1⅜ inch in diameter. For the following drawing operations, the reductions are as follows:

Third drawing operation reduces the shell from 7½ to 6⅛ inches or 1⅜ inch in diameter.

Fourth drawing operation reduces the shell from 6⅛ inches to 5 inches or 1⅛ inch in diameter.

Fifth drawing operation reduces the shell from 5 inches to 4 inches or 1 inch in diameter.

These are the reductions in size of the upper part of the shell. The reductions in the re-drawing operations for the lower part of the shell are still less than those for the upper part, as follows:

For the first drawing of shoulder the shell is reduced from 4 to 3¼ inches or ¾ inch in diameter.

For the second drawing operation of shoulder, the shell is reduced from 3 1/4 to 2 9/16 inches, or 11/16 inch in diameter.

For the third drawing operation of shoulder, the shell is reduced from 2 9/16 to 2 1/2 inches, or 1/16 inch in diameter.

It is absolutely necessary that all the drawing punches have vent holes in them, so that the shell, when drawn, will not stick to the punch or die and work havoc with the press. Another point which should be carefully considered is the diameter of the blank. The blank should be made of such a size, that when the cup is finish drawn there will be from ⅜ to ½ inch to trim off. The reason for this is that the upper or open end of the shell becomes hard and crystallized, owing to the excessive drawing, and extremely brittle.

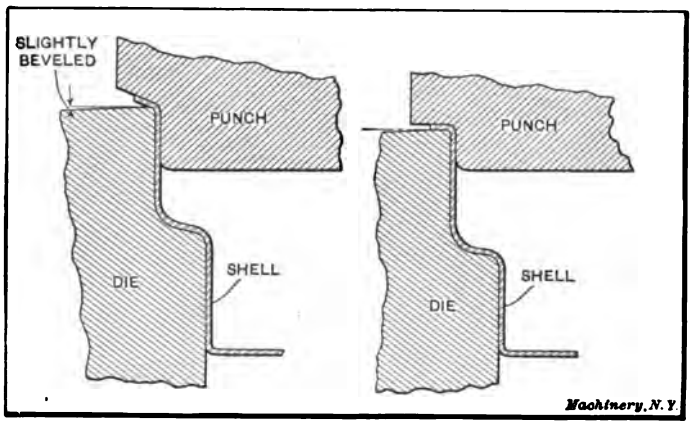


Fig. 18. Punch and Die for Starting the Flange

Fig. 19. Punch and Die for Finishing the Flange

The crystallized part of the shell should be entirely removed so that, in flanging, the shell will not split or crack at the top edges. The writer would suggest that the shell, during the drawing operations, should pass through several annealing and pickling operations, so as to make it more ductile.

After the shell has been drawn to the correct length, it is ready to be trimmed. This is done before the flanging and is usually accomplished in a lathe of the roller-spindle variety. A method which could be used in trimming this shell is shown in Fig. 17. The shell is placed on a cast-iron chuck *A* which is screwed to the nose of the spindle. This cast-iron chuck is made slightly smaller in diameter than the inside of the shell. A hardened steel ring *B* is driven on the cast-iron chuck, and acts as a cutting edge. The shell is cut off by means of a hardened roller *C*, which is made circular in shape but has no cutting teeth. It is held on a pin *D* which is driven into a holder *E*. This holder is held in the toolpost of the lathe. The shell is held on the chuck by means of a revolving backplate *F* which, in turn, is held in a holder fitted to the tailstock of the lathe. The edges *G* and

H of the roller and hardened ring, respectively, are set so that they will slide freely past each other. The shank of the chuck is made considerably smaller than the shell, so that the part cut off can be easily removed.

The flanging of the top of the shell is the next operation. This can be done in two ways, one of which is shown in Figs. 18 and 19. This method requires two punches, both of which have hardened steel faces, but the same die can be used for both operations. The first punch, as shown in Fig. 18, starts the flange, and the second punch, as shown in Fig. 19, flattens it. The top face of the die is made of hardened steel, and is beveled slightly to allow for the spring in the material. The other method of forming the flange is shown in Fig. 20. This the writer considers better and more satisfactory than the

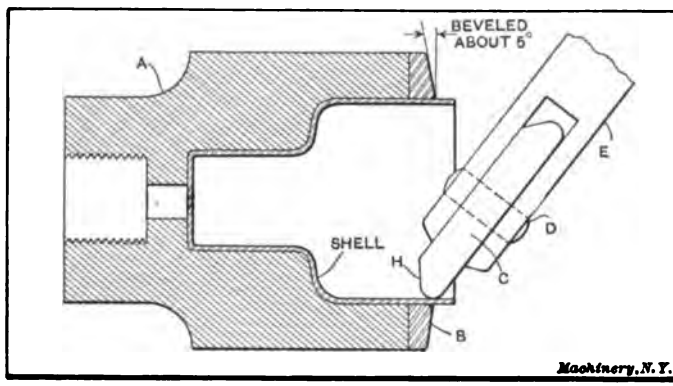


Fig. 20. Another Method of Flanging the Top of the Shell

one shown in Figs. 18 and 19. The flanging is accomplished in the lathe, the shell being held in a cast-iron chuck *A* which is screwed to the nose of the spindle. A tool-steel face *B* is fastened to the cast-iron chuck, over which the flange is bent by means of the hardened roller *C*. This roller is held on a pin *D* which is driven into a holder *E*, the latter being held in the toolpost of the lathe. The roller is applied in the manner shown in the illustration, and is brought from the inside out along the face. The face of the tool-steel ring *B* is beveled at about 5 degrees, to allow for the spring of the metal. Care should be taken to turn the flange over evenly and without buckling. The roller should be held at the correct angle to the work, to give the best results. When the flange is turned over, it is flattened down by the flat face *H* on the roller. If the suggestions given are carefully followed no difficulty should be encountered in making this shell.

Making a Ferrule in One Operation

Figs. 21 to 23 illustrate a ferrule and the method of blanking, drawing, redrawing and finishing the hole in the bottom, in one operation. The die, which is shown in Fig. 21, is not a complicated one,

nor is it difficult to construct. That it is practical is obvious from the fact that it is producing ferrules at the rate of 1080 per hour. This shows the possibility of combining several operations in one.

The punches and dies were made of 0.12 point carbon steel, and used in a No. 3½ Bliss double-acting press. This press was used because there was no smaller press available in which the dies could be

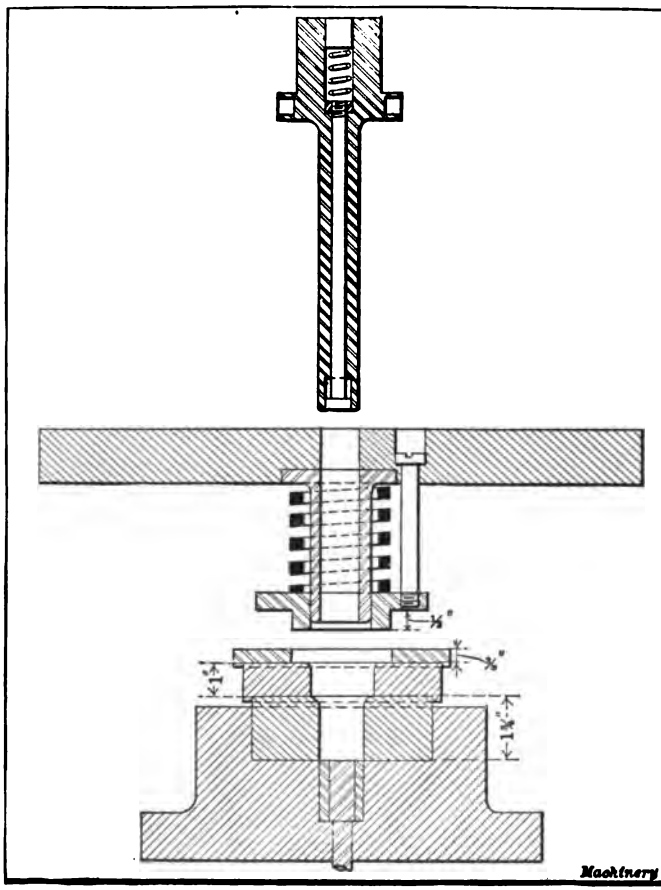


Fig. 21. Die for Blanking, Drawing, Redrawing and Punching the Hole in a Ferrule in One Operation

used. The tools, on account of their small size, were made from bar stock, but in general, drawing punches and dies, except for small work, should be made either of cast iron or cast steel. In some cases a cast-iron die is just as efficient as one made of tool steel. It is the writer's practice to make a pattern and cast the die, punch or blank-holder as nearly to size as possible, thus dispensing with the machining and bench work. In making this die, the first thing done by

the bench-hand was to make male and female sheet-metal gages, about 1/16 inch thick. These gages must be full size, not half gage, as it is very easy for a lathe-hand to misread his micrometer one turn, 0.025 inch, but there is no excuse for a workman not making a part right when he has gages to work to, and, moreover, it is quicker to work to the gages.

This set of tools, as can be seen at a glance, requires only straight lathe and grinder work; therefore, after the bench-hand had made the templets, he had no more to do with the tools until they were turned, hardened and ground and came back to be assembled. The cutting punch was only hardened on the end, leaving the shoulder soft, thus making it possible to get a perfect alignment for the two $\frac{5}{8}$-inch

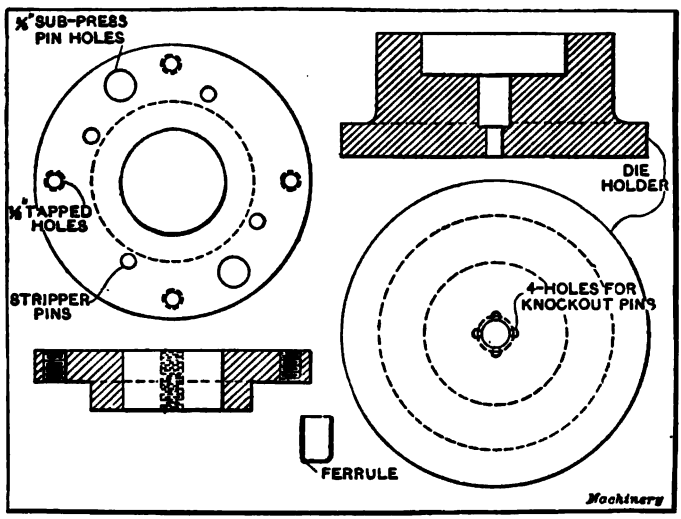


Fig. 22. Blanking Punch and Blank Holder. Fig. 23. Die-holder

sub-press pins, after the die and punch were hardened and ground. The blanking die, as well as the first and second drawing dies, had to be true with the outside diameter, as each in turn was recessed out for the other.

The second operation drawing punch, which is also the re-punching die, is provided with a spring stripper. This stripper has a rod passing through the punch, held in place by a nut. Behind the stripper is a spring, held in place by a blind screw. Six 5/16-inch holes are drilled in the shoulder of this punch, for holding the punch to the ram of the press. By making the spring stripper in this manner, the scrap from the $\frac{3}{4}$-inch hole in the bottom of the ferrule is retained on the inside of the shell when it is ejected. The spring stripper which operates the blanking punch is turned down, so as to take up as little room as possible. Figs. 22 and 23 show the construction of the blanking punch and the die-holder, respectively.

CHAPTER II

EXAMPLES OF DRAWING, FORMING AND BENDING DIES

The shell shown in section in the dies at *C* in Fig. 24 is an unusually difficult piece to draw from thick brass, the principal difficulty being due to the fact that the metal will not draw over anything approximating a sharp corner. The usual method of producing a shell of this kind—reducing it from larger cups by successive drawing operations—was tried without success. Finally the method shown in the illustration was tried, and it was found that satisfactory results could thus be obtained. This makes the operation akin to squeezing

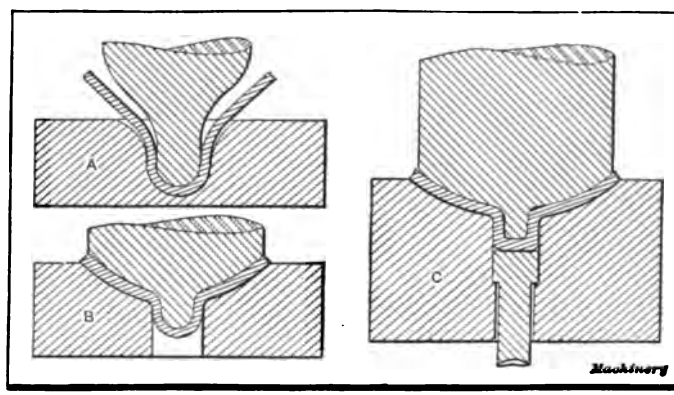


Fig. 24. The Three Dies used to produce the Shell

rather than drawing, the point being to protrude enough metal in the first and second operations to allow pressure from below to be applied in a third operation, shaping the stock and setting it to the required dimensions.

In the dies shown at *A* the object is to start the thick metal in a downward direction by means of the comparatively loose fitting punch and die shown. The edge of this die is very gradually rounded so that the metal will slide over easily. The second operation, which is performed in the dies at *B*, consists of shaping the shell around the depression already made, and the finished shape is the result of the operation performed in the dies at *C*.

The shell is started from a round blank, and two annealings are required to bring the metal to the finished shape. Subsequent piercing and cutting operations are afterward performed on the piece, but these do not differ from the general run of such operations.

Drawing Rounding Covers in One Operation

Figs. 25 to 28 show a punch and die for drawing rounding covers to the full depth in one operation, without leaving a wrinkle, finishing them four at a time. As is well known, it is a difficult propo-

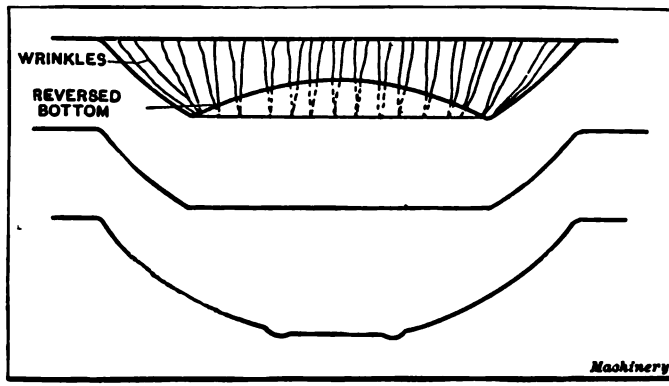


Fig. 25. Top View: Cover produced by Old Method of Drawing in One Operation, causing Wrinkles, even with Reversed Bottom. Middle View: First Stage in Drawing Cover in One Operation. Lower View: Finished Cover

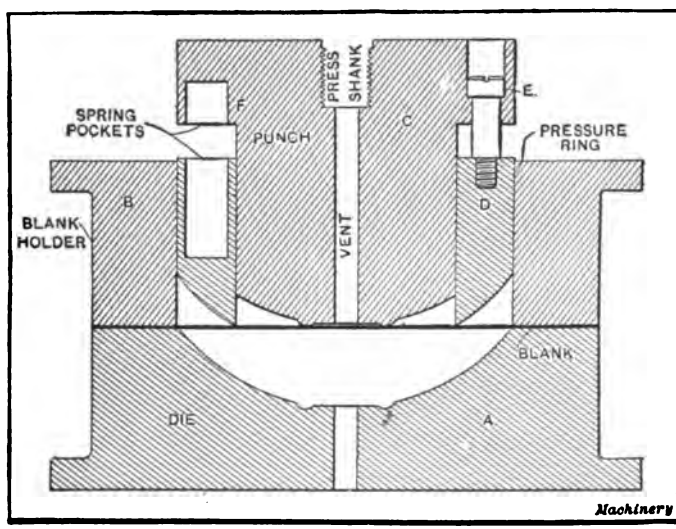


Fig. 26. Cover Blank Gripped by Blank-holder preparatory to the Drawing Operation

sition to draw a shell to the shape shown; such a cover cannot be drawn in one operation by the standard double-action method, for the stock would wrinkle and tear, making it necessary to spin out the wrinkles, as the punching would not stamp them out. An additional operation is required to finally stamp them all uniformly.

Fig. 25 shows at the top a view of the old-style method of making this cover which shows how the bottom has been reversed to stretch the metal and give enough stock for the crown and sides, the latter being very much wrinkled and sometimes "lapping." Considering the fact that these covers are of large size, ranging from 15 to 22 inches in diameter at the edge of the rounding top, and that each time the blanks "lapped" it meant a loss of four, this proved to be a costly method. When they did come through all right, not only did the wrinkles have to be rolled out, but the blanks had to be stamped besides to bead them and reverse the shell.

To overcome these drawbacks and to eliminate the numerous handlings, a triple-acting die for use in a double-action press was designed.

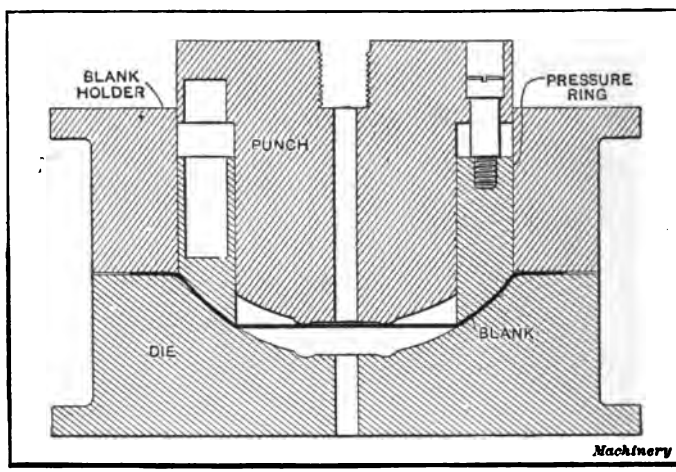


Fig. 27. First Step in the Operation, the Pressure Ring drawing the Blank to the Form shown in Middle View, Fig. 25

This made the complete shell, four at a time, in one operation to the shape indicated in Fig. 25 at the bottom. Fig. 26 is an assembled view of the die, showing all its parts. A blank is shown in position for drawing, being held by the blank-holder and die in regular double-action fashion, with the punch just touching. The die A is an ordinary double-action drawing die, made of cast iron, formed to the exact shape of the finished rounding cover, with a vent hole through the center of the bottom through which the ejector works. The drawing faces of both the die and the blank-holder are the exact size of the blank; the blank-holder *B* is of the regulation, double-action type, made of cast iron, with an opening through the center to allow the drawing punch to slide through easily. Both the die and the blank-holder are secured to the press by means of a clamping flange. The punch *C*, it will be noted, contains the special feature that made the drawing of the finished shell a possibility. The punch, itself, is made of cast iron and is tapped at its base and thereby secured to the

shank of the press. The outside diameter of the punch is just large enough to slide through the blank-holder easily. A shoulder is turned around the body of the punch over which there is a sliding pressure ring *D*, held in position by several shoulder screws *E*, between which are spring pockets containing heavy spiral springs of sufficient strength to draw the shell to the shape indicated in the middle view in Fig. 25; the punch has corresponding spring pockets. When making the punch, this ring *D* was held back against the shoulder of the punch *C* and both faces were machined while in this position to give the internal form of the rounding cover. The normal position and appearance of the punch and ring are shown in Fig. 26.

The action of the punch and die in drawing the shells is as follows:

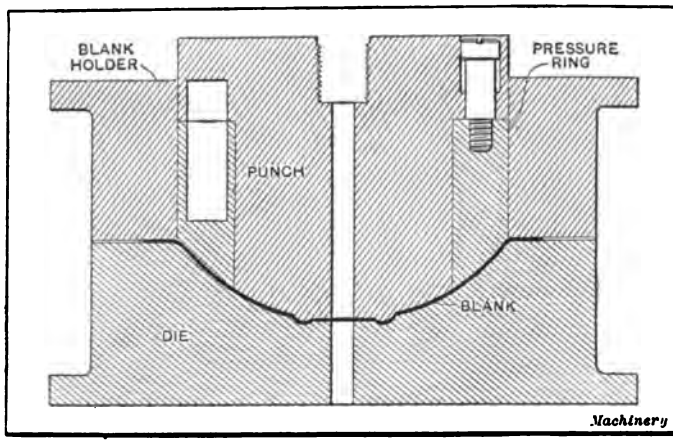


Fig. 28. Final Step in the Operation, the Punch descending within the Pressure Ring to form the Bottom, leaving Blank as shown in the Lower View, Fig. 25

After the blanks have been placed in position on the top face of the drawing die *A*, the blank-holder *B* attached to the pressure part of the double-action press descends until it holds the blanks firmly against the die face. The punch pressure ring *D* then comes down, the heavy springs in the pockets being sufficiently strong to perform the first drawing operation which brings the blank to the shape shown in the middle view in Fig. 25; Fig. 27 shows the punch and die after this operation, when the pressure ring has bottomed in the die, acting as an inner blank-holder while the punch descends still further to form the central part of the blank. The cover finally assumes the shape indicated in the lower view in Fig. 25, the relative positions of the members of the punch being shown by Fig. 28. Altogether, the action was perfect and no defective shells were produced, the drawing being easy and uniform.

The examples of drawing and forming shown on the previous pages have been selected from a great variety of punch and die constructions, because they exhibit clearly the principles involved.

Some Interesting Drawing and Curling Dies

The following interesting examples of drawing and curling die work were obtained in the shop of the Budd & Ranney Mfg. Co., Columbus, Ohio, manufacturers of Budd & Ranney gas engines, special machinery, tools, and all sorts of punch press work. The firm devotes the greater part of its attention to the manufacture of special tools, punches and dies, etc. Some of the punch and die problems submitted to it and successfully solved are described in the following.

Fig. 29 shows a drawing punch and die which was made for producing the brass top for a wire gas globe shown assembled at *A* in

Fig. 29. Drawing Die and Punch and Brass Top after Drawing and Trimming Operations

Fig. 30. This globe is a recently patented protector for gas mantels. The wire mesh permits a free circulation of the air around the burner. This globe fills the additional function of a fire prevention device, because if the mantel should break, it is caught and held by the wire basket.

The top for this wire gas globe is made from 0.010 inch thick sheet brass and is blanked and drawn up completely to shape in one operation. The piece is shown after this operation at *A* in Fig. 29, and also at *B* in Fig. 31. The die and punch used for this purpose are shown at *B* and *C* in Fig. 29, and are used in a single-action punch press. As indicated in Fig. 31, this brass top is produced inverted and not drawn through a die in the usual manner.

The die *B*, Fig. 29, consists of a cast-iron bolster *a*, bored to receive the blanking die *b* which has an irregular top face providing for a shearing cutting edge. This blanking die is held in place by ring *c*

and the screws shown. The forming part of the die proper consists of a circular form *d*, made to suit the internal diameters and shape of the brass top, and held in the recess in the bolster by screws and dowels. Projecting through from the base of the die bolster are eight pins *e* which rest on a steel ring bearing on top of a rubber spring pad, 10 inches long and 6 inches in external diameter, having

Fig. 30. Curling Die and Punch for a Steel Ring; Ring in its Various Stages of Formation; and Complete Wire Gas Globe in which Ring is used

a 3½-inch hole. This rubber spring pad is held on a bolt screwed into the bolster.

When in operation, pad *f* (shown removed in Fig. 29), rests on pins *e* and provides a support for the sheet while the blank is being cut by the outer edge of the punch *C*. Then, as the ram of the press continues to descend, pad *f* is forced down by punch *C*, compressing the rubber spring pad and at the same time allowing the recess in

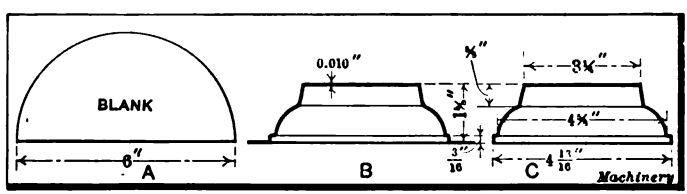


Fig. 31. Successive Drawing Operations on a Brass Top for a Wire Gas Globe

the punch (made to suit the outside diameters and shape of the brass top) tc force the work over forming die *d*, thus producing the desired shape. The bar *g* is used as a guide for the sheet, while the finger *h* locates the sheet for each successive blank.

It will be seen from Figs. 29 and 31 that there is considerable excess material left around the edge of the brass top after it has been formed to the desired shape. The chief reason for this is that the brass top, which is made from comparatively thin stock, can then be nicely trimmed in a succeeding punch and die with little difficulty. On the other hand, if this excessive material were not provided for, it would be much more difficult to draw the cup successfully, and would also increase the difficulty of trimming. As it is also neces-

sary to cut out the bottom of this brass top in a succeeding operation, the trimming and blanking can be done in the same die.

The punch and die used for trimming the wire gas globe is shown in Fig. 32. This punch and die is also held in a single-action press, the punch being held to the ram, while the die is held in a bolster on the bed of the press in the usual manner. The trimming die consists of two steel rings or dies; the larger one *A* is doweled and screwed to the top face of the bolster *B*, while the trimming ring for the bottom of the brass top is let into the bolster. The distance between the top faces of the two trimming rings is slightly greater than the corresponding distances on the brass top.

Fig. 32. Trimming Punch and Die for Brass Top set up on a Single-action Press

The punch consists of two main parts *C* and *D*. The lower part *C* which continues up, in shank form, into the ram of the press, is used to cut out the bottom of the brass top. Part *D* is in the form of a ring surrounding punch *C*, and is held down on a shoulder on the latter by stiff coil springs located between the rings *D* and *E*, the latter of which bears against the lower face of the press ram.

The operator places the work in the die, as shown in Fig. 32, and then trips the press, when punch *C* descends and cuts out the bottom of the brass top. Upon further downward movement of the ram, punch ring *D* comes in contact with the flange on the work, pressing it tightly against the die ring *A* and compressing the coil springs. This action continues until punch ring *D* comes into contact with ring *E*, when further upward movement of the punch ring is prevented, and the excess metal is sheared from the brass top. The

disk cut out from the bottom of the work falls to the floor, while the ring and top are removed from the die by the operator with the stick shown lying on the bolster of the press. A pile of finished pieces is shown at *F*, Fig. 32, and one single top at *D* in Fig. 29. In this single-action press it is possible to turn out 4000 wire gas globe tops in 10 hours, this production including both operations—drawing or forming, and trimming.

Another interesting example of press drawing of sheet metal is shown in Figs. 33 and 34. Fig. 34 shows the various press operations diagrammatically, and illustrates the successive steps followed in the production of a steel cup. The most remarkable feature is that this cup is completed in four operations without annealing. The material used is mild steel 0.042 inch thick. Upon referring to *B* and *C* in Fig. 33, and also to *C* and *D* in Fig. 34, it will be seen how

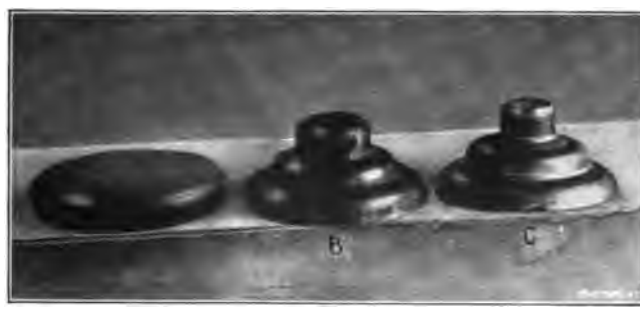


Fig. 33. Successive Drawing Operations on a Steel Cup, which is drawn to Shape without annealing (Last Operation not shown)

this feat is accomplished. Instead of endeavoring to produce square shoulders and straight sides in the preliminary drawing operations, the corners are formed with liberal radii and the sides inclined at an angle with the axis of the cup. The object in making the cup of this shape is to assist the metal in "flowing," anad to distribute the strains throughout the greater portion of the blank.

Sharp corners and straight sides tend to put all the strain on the corners and cause rupture at these points. Furthermore, by forming the cup in the manner shown, the final operation simply shapes the work by stretching it at the corners, without increasing its length to any perceptible extent. Upon cutting one of these cups in two, it was found that the metal was only slightly reduced in thickness at the point *a*, in section *E*, Fig. 34, the remainder of the cup being practically of uniform thickness. As the top of the cup had to be of an exact diameter externally, the metal was drawn more at this point, to remove what spring still remained in it. This steel cup was produced in dies of practically the same construction as those shown in Fig. 29, in a single-action punch press.

It is the practice in one shop in making drawing dies, to calculate roughly the diameter of the blank required and to make the

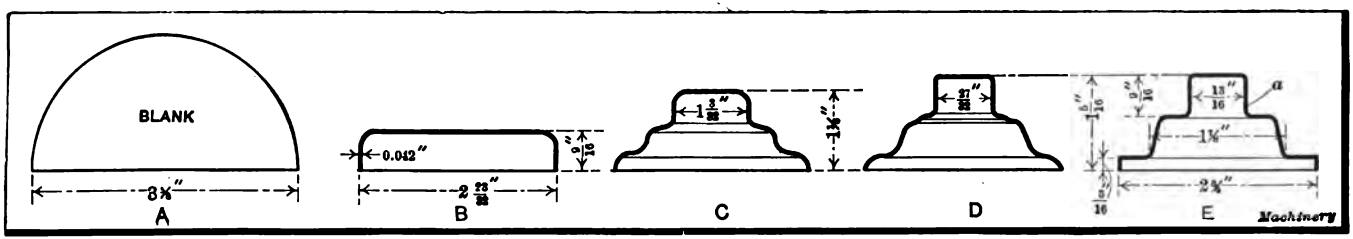


Fig. 34. Press Operations on the Steel Cup also shown in Fig. 33

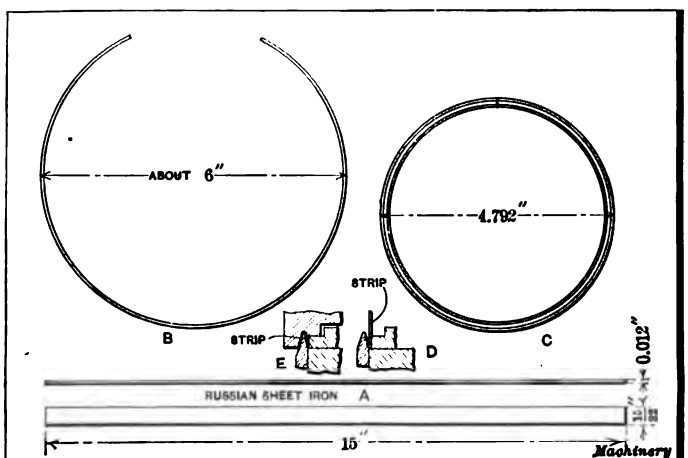


Fig. 35. Steel Ring in Various Stages of Formation, and Diagram illustrating how it is held and curled

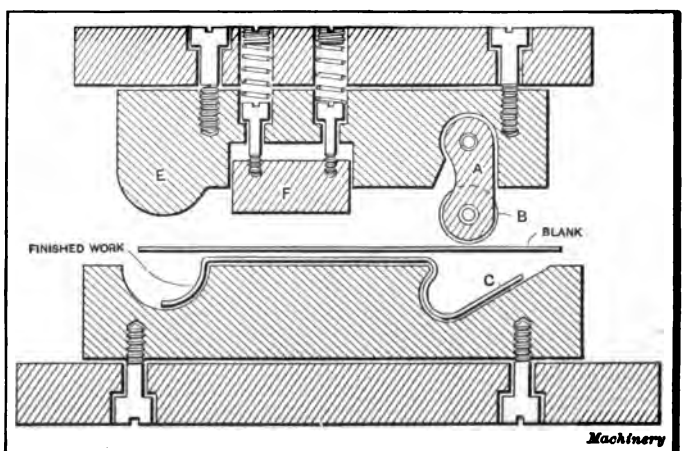


Fig. 36. Novel Form of Bending Die

successive drawing and redrawing dies before making the blanking die. A simple method of obtaining the approximate diameter of the blank is to multiply the circumference of the finished cup by the height, and then add the area of the bottom, which gives the area of the blank; then find the diameter of a circle whose area equals this area. This rule applies to cups that must be made of a uniform thickness on the sides and bottom and that are of approximately cylindrical shape. For irregular shaped cups the usual practice is to take the mean diameter and use the rule previously given.

It is impossible by any known method to calculate the exact diameter of blank required, as the "stretch" of the material cannot be definitely determined except by trial. Considering this, it is good practice to follow the method suggested—that is, making the successive drawing dies before the blanking die. A blank can be cut out and filed to the approximate diameter in a short time, then passed through the drawing dies, and when completely formed, if found to be of the required length, the blanking die can be made to the same diameter as was this trial blank. If, on the other hand, the shell is too short or long, the diameter of the blank can be increased or reduced accordingly, and the same procedure followed until the exact diameter of the blank is obtained.

An interesting curling die for forming the ring *B*, Fig. 30, used in holding the wire mesh in the gas globe shown at *A*, is shown in the same illustration. The ring is shown in its successive forming steps at *A*, *B* and *C* in Fig. 35; *A* is the strip from which the ring is made, cut from a sheet of Russian iron to the dimension shown. The first step is to bend the blank into a hoop in a pair of bending rolls, bringing it to the shape shown at *B*, and also at *D* in Fig. 30. It is now ready for the curling die, which is held in the press shown in Fig. 32.

Referring to Fig. 30, the curling die shown at *F* consists of a bolster *a* having a projection around which the forming ring or die *b* is held. Retained inside the forming die, by a ring *c* and four screws *d*, are four jaws *e*. These jaws are provided with elongated holes in which screws *d* fit, and are acted upon by open-wound coil springs located in front of the eight headless screws *f* placed equidistant around the die ring. The inner sides of the jaws are provided with a projection and form a tapered hole into which the tapered spring-operated pin *g*, held in punch *G*, fits.

In operation, punch *G* is held in the ram of the press and die *F* is fastened to the bed. The operator grasps the partly bent band *D* with both hands, placing it between jaws *e* and die ring *b*, as illustrated diagrammatically at *D* in Fig. 35. Then when the ram of the press descends, the tapered pin *g* comes in contact with jaws *e*, forcing them out and thus gripping the hoop securely. As the ram continues to descend, the tapered pin recedes, allowing the groove *h* in punch *G* to force the band over the die ring in the manner shown at *E* in Fig. 35. When the ram of the press ascends, the jaws are re-

turned to their normal position by the eight coil springs, thus freeing the ring and allowing it to be easily removed by the operator.

A Bending Die

Fig. 36 shows a die designed for the Eagle Tool Co., Cincinnati, Ohio, to meet the requirements of a certain bending operation on 16 gage sheet metal. It will be seen from the illustration that a swinging arm *A* is pivoted at one end of the punch; this arm carries a steel roll *B*. When the punch descends this roll bends the stock down into the die at *C;* when the downward travel of the roller is checked by the die, the arm *A* swings to the left and continues to move in this direction until the roller has formed the work in the die as shown. The left hand end of the work is formed between the die and the extension *E* on the punch. Before the punch has reached the end of its

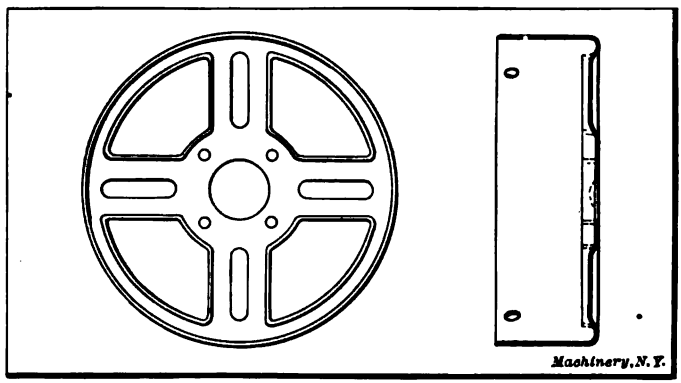


Fig. 37. Aluminum Shell to be made

downward travel, the gripper *F* engages the work and holds it in position through the tension of the two springs shown in the illustration. This prevents any movement of the work during the final stages of the bending operation.

Press Tools for Aluminum Shell

The spoked aluminum shell shown in Fig. 37 is about four inches in diameter and one inch deep. It has four spokes, or arms, radiating from a hub in which a shaft hole and four rivet holes are punched. These holes are used for attaching the aluminum shell to the bearings of the hub on which it is used. Stiffening "lips" around the openings and spokes are formed, and the ribs or spokes themselves are embossed to add to the strength of the shell. Four rivet holes punched through the rim of the shell serve to attach it to an exterior band.

This shell was made in the following manner and with excellent results: The blanking, drawing and embossing is done in one operation in a double-action press, using the die shown in Fig. 38. The blank-holder *A* is made of cast iron, and a hardened tool-steel blank-

ing die *D* is fastened to it, which not only acts as a die, but also serves to hold the blank in position while the drawing operation is taking place. *B* is the cast-iron drawing punch, to which is attached a hardened steel face *K*. This face *K* contains the embossing recess

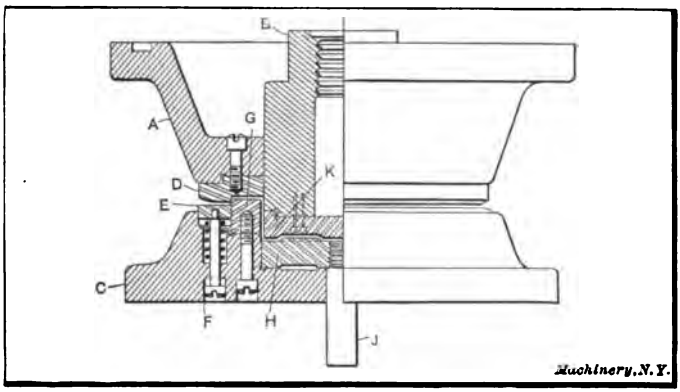


Fig. 88. Combination Blanking, Drawing and Embossing Die for the Shell

for the spokes, into which the metal is forced by the embossing punch *H* held to the lower member. The punch *H* also acts as an ejector after the drawing and embossing operations have been completed, and is actuated by the stem *J* and the knock-out mechanism of the press.

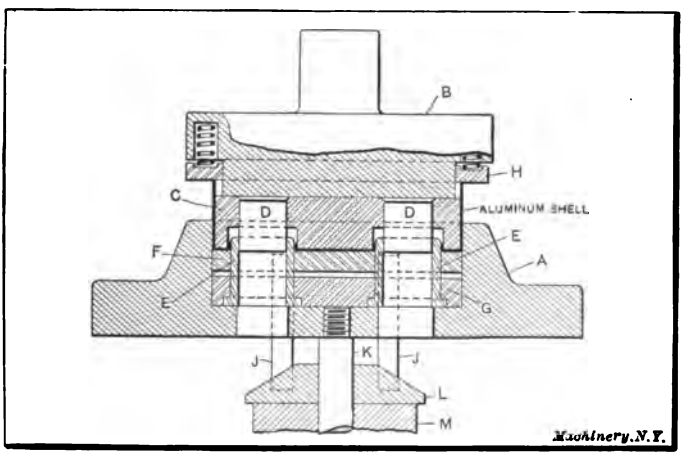


Fig. 89. Combination Piercing and Ribbing Die

The die-shoe *C* is made of cast iron, and is bored out to receive the blanking punch *G* over the inner edge of which the shell is drawn after blanking. The stripper ring *E*, which is made of soft steel and passes around the periphery of the die *G*, is limited in its travel by the shouldered screws *F*, and acted upon by six helical springs. There are

several vent holes in the drawing punch and through the plate *H* and the base of the die-shoe, the purpose of which is to allow the air to escape while drawing, and enter while stripping and ejecting the shell. The shell is drawn entirely into the ring *G*, and of course, must be trimmed afterward. This is performed in a trimming lathe, although similar shells are sometimes drawn to the depth required, and a flange left on them, so that they may be trimmed off by a simple blanking die. However, the method of handling this operation lies entirely with the designer, although it should be governed to some extent by the requirements of the shell.

After the shell is drawn into cup form, the next operation is to pierce the openings to form the spokes, and turn up the "lips" around these openings. Both these operations are performed in the die

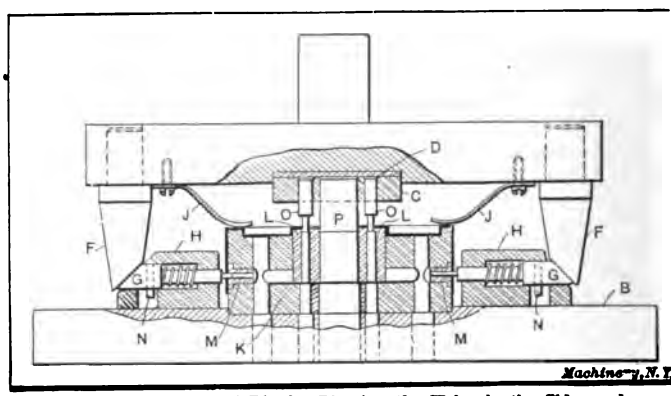


Fig. 40. Punch and Die for Piercing the Holes in the Sides and Bottom of the Shell

shown in Fig. 39, which is held in a single-action press. The die-shoe *A* and the punch-holder *B*, respectively, are made of cast iron, the die-shoe being bored out to receive the soft-steel die carrier *G*, and the ejector plate *F*, which is also made of soft steel and is actuated by four studs *J* resting on a cast-iron plate *L*. This cast-iron plate *L* is pressed upward by a rubber pad *M* which slides on stud *K*. The die-bushings *E* are flanged on the bottom, as shown, and are held in the carrier plate in the usual manner. They serve not only as dies for piercing, but also as drawing punches to draw the stiffening "lips" on the shell. The drawing die *C* is held on the punch-holder *B*, and carries the piercing punches *D*, which are set ahead of the drawing die so that they will pierce the stock before the die begins to draw the "lips." A stripper ring *H*, actuated by coil springs as shown, is limited in its travel by the drawing die *C* upon which it comes to rest on the up-stroke of the ram. All the screws and dowel pins used for holding the various members in their respective holders are omitted for the sake of clearness.

The shell is now ready to have the holes around the rim and the small holes in the bottom pierced. These operations are accomplished

in the die shown in Fig. 40 which is held in a single-action press. A circular disk *B* of cast iron serves as a base for the die, and to it is attached the die-anvil *K*, of soft machine steel. Die-bushings *L* and *M* are driven into the anvil *K* for piercing the holes in the rim and in the bottom of the shell. Recesses are cut in the block *K* to receive the "lips" around the spoke openings. The cast-iron punch-holder carries two flat springs *J*, which serve to hold the shell on the anvil when the holes are being pierced. The punch-holder also carries four studs *F* (only two of which are shown) that operate the piercing punches *G*. These piercing punches *G* fit in blocks *H* held to the die-bolster, and are retained in the blocks *H* by the small studs *N*

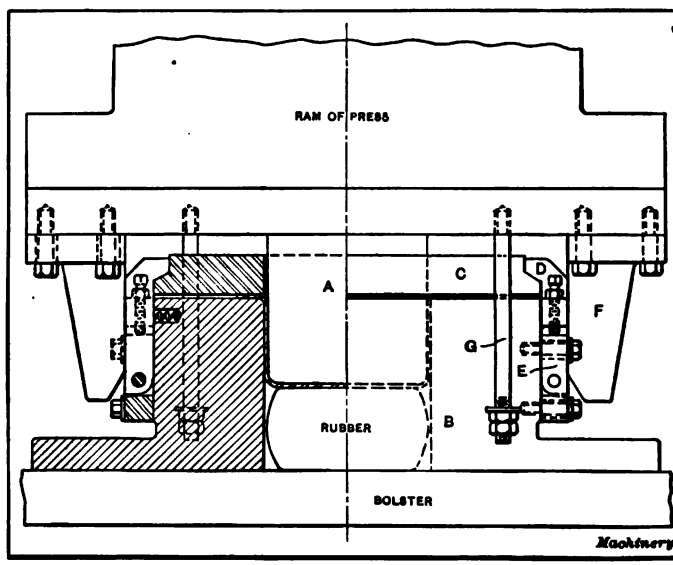


Fig. 41. Die for drawing Cups in a Long-stroke Single-acting Press

working in elongated holes in the block. These small studs or pins *N* also serve to prevent the punches *G* from turning around, so that their beveled ends are always presented properly to the studs *F*. The punches *G* are withdrawn when the ram of the press ascends, by coil springs, as shown. The punches *O* and *P*, for piercing the holes in the bottom of the shell, are held in a machine-steel block *C*, which is backed up with a hardened tool-steel block *D* inserted in the punch-holder. The blocks *C* and *D* are doweled together and held to the punch-holder.

Making this aluminum shell in the manner described, gives a uniform product, and the tools are of such a character that they are easily repaired and are not very costly. While these tools are of a special character, a number of the features incorporated in them could be used for a variety of purposes.

Drawing in a Single-Acting Press

Fig. 41 shows a method for drawing steel cups, such as would usually be made on a double-acting press. No double-acting press was available, but only a long-stroke single-acting press of sufficient capacity to do the job. The die was made as follows: On the die *B* were bolted some U-shaped pieces *E* which carried the holding hooks *D*. These hooks *D* could be adjusted to any desired degree of tightness by setting down the pieces *E* with the set-screws provided and then clamping them securely in place. The blank-holder *C* was suspended on four bolts *G*, and these bolts were adjusted to the proper length so that the blank-holder *C* was laid on the blank early in the stroke; then closing lugs *F* engage the holding hooks *D* and force them in on the beveled ledge of the blank-holder. The lugs *F* then slide along the back of hooks *D* during the remainder of the stroke.

On the up stroke the closing lugs leave the hooks *D* which are immediately thrown open by springs provided for this purpose, and then the blank-holder *C* is lifted up by the suspension bolts *G*. The formed piece is loosened in the die by the rubber block, or, if necessary, a positive stripper can be provided. At first the closing lugs *F* were made solid with the punch-holder, but after several were broken by dirt or other foreign substances getting under the blank, a new holder was made with the lugs bolted on, so that the bolts would allow the lugs to give enough to prevent breakage.

This die is more expensive than would be required for a double-acting press, but works nearly as well and makes it possible to do the work with the equipment at hand.

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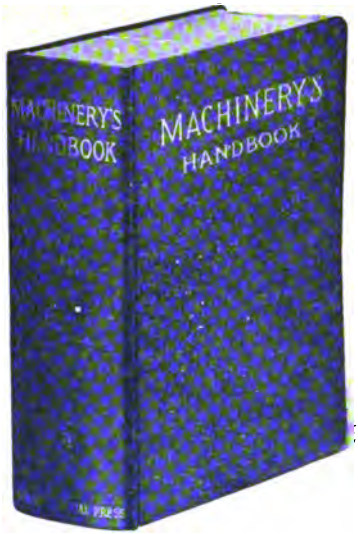

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